Troubleshooting Vacuum Systems

Steam Turbine Surface Condensers and Refinery Vacuum Towers

Authored by

Norman P. Lieberman

Contents

Preface		**xiii**
Introduction		**xv**
Definition of Terms		**xix**
Other Books by Author		**xxiii**
1	**How Jets Work**	**1**
1.1	The Converging-Diverging Ejector	1
1.2	Interaction of Steam Nozzle with Converging-Diverging Diffuser	5
1.3	Compression Ratio	6
1.4	Converging-Diverging Ejector	7
1.5	Velocity Boost	9
1.6	Surging	10
1.7	Critical Discharge Pressure	11
1.8	Observing the Conversion of Heat to Velocity	12
1.9	Jet Discharge Pressure	13
1.10	Reducing Primary-Jet Discharge Pressure	14
1.11	Bypassing First Stage Ejectors	15
2	**Making Field Measurements**	**17**
2.1	Getting Started	17
2.2	How to Unscrew Steel Plugs	23
2.3	Effect of Barometric Pressure on Indicated Vacuum	24
2.4	Use of Piccolo	25
2.5	Measuring Deep Vacuums using an Hg Manometer	27
2.6	Measurement of a Deep Vacuum without Mercury	28
2.7	Measuring Condensibles in Feed to First Stage Ejector	30
2.8	Identifying Loss of Sonic Boost by Sound	31

	2.9	Identifying Air Leaks	32
	2.10	Air Leaks in Flanges	34
	2.11	Vacuum Measurement Units	35
3	**Tabulation of Vacuum System Malfunctions**		**39**
	3.1	Tidal Flop in Delaware	40
	3.2	Critical Discharge Pressure	43
	3.3	Fouling in Final Condenser	43
	3.4	Reduction in Back Pressure	45
	3.5	Loss of LVGO Pan Level	45
	3.6	Variations in Cooling Water Temperature	47
	3.7	Multi-Component Malfunctions	50
	3.8	Partial Tabulation of Vacuum System Malfunctions	51
4	**Effect of Water Partial Pressure on Jet Efficiency**		**55**
	4.1	Vapor Pressure of Water Limits Vacuum	56
	4.2	Reminder about Water Partial Pressure	59
	4.3	Air Leaks in Steam Turbine Surface Condensers	59
	4.4	Variable Cooling Water Temperature	60
	4.5	Loss of Sonic Boost	60
	4.6	Relative Jet Efficiency	62
	4.7	Definition of "Vacuum Breaking"	63
	4.8	Critical Discharge Pressure Exceeded	64
5	**Air Leaks**		**67**
	5.1	Upper Explosive Limits	67
	5.2	How to Find Air Leaks	68
	5.3	Diffuser Air Leaks	69
	5.4	Air Leaks on Vacuum Towers	70
	5.5	Air Leaks in Heater Transfer Lines	71
	5.6	Air Leaks – Turbine Mechanical Seal	72
6	**Sources and Disposal of Hydrocarbon Off-Gas**		**75**
	6.1	Evolution of Cracked Gas	75
	6.2	Sources of Cracked Gas	78
	6.3	Cracked Gas Evolution from Boot	80
	6.4	Air Equivalent	81
	6.5	Overloading Vacuum Jets	84
	6.6	Excess Cracked Gas Flow	85

	6.7	Field Checking Gas Flow Meter in Vacuum Service	85
	6.8	Surging 3rd Stage Jet Bogs Down Primary Jet	89
	6.9	Exchanger Leaks Overloads Jets	90
	6.10	Poor Vacuum Tower Feed Stripping	92
	6.11	Level Connection Purges and Pump Mechanical Seal Gas	94
	6.12	Effect of Heater Outlet Temperature	95
	6.13	Extracting H_2S from Vacuum Tower Off-Gas Upstream of Ejectors	97
	6.14	Disposal of Seal Drum Off-Gas	99
	6.15	Fouling of Waste Gas Burner	100
7	**Motive Steam Conditions**		**101**
	7.1	Effect of Wet Steam	102
	7.2	Water in Motive Steam	103
	7.3	The Tale of Weak Steam	104
	7.4	Internal Freezing of Steam Nozzle	105
	7.5	High Pressure, Superheated Motive Steam	108
	7.6	Effect of Moisture Content of Saturated Steam on Temperature	108
	7.7	Steam Pressure Affects Vacuum	109
	7.8	Effect of Superheated Steam	111
8	**Mechanical Defects of Ejectors**		**113**
	8.1	Steam Nozzle Testing	113
	8.2	Other Mechanical Defects of Jets	114
	8.3	Fouled Steam Nozzles	117
	8.4	Diffuser Erosion	118
	8.5	Repair of Ejector Body	119
	8.6	Changing Worn Steam Nozzles	119
	8.7	Restoring Critical Flow	120
9	**Condenser Fouling and Cleaning**		**123**
	9.1	Fouling Mechanism in Condensers for Refinery Vacuum Towers	123
	9.2	Fouling Due to Chemical Additives	124
	9.3	Minimizing Condenser Fouling in Vacuum Towers	125
	9.4	Fouled Pre-condenser	126

9.5 Fixed Tube Sheet Condensers 128
9.6 Cleaning Condensers On-Stream 129
9.7 Optimum Condenser Bundle Configuration 130
9.8 Chemically Cleaning Condensers 130
9.9 Ball Cleaning Condenser Tubes 131
9.10 Corrosion Control by Better Desalting 132

10 Pressure Control of Vacuum Towers 135
10.1 Positive Feedback Loop 141

11 Condenser Cooling Water Flow 143
11.1 Cooling Water Flow Configuration 143
11.2 Air Evolving from Cooling Water Reduces Cooling Water Flow 145
11.3 Cooling Water Pressure to Surface Condensers 148
11.4 Tube Leaks 149

12 Condensate Back-Up in Condensers 151
12.1 Undersized Condenser Drain Nozzle 153
12.2 Seal Drum Level Indication 155
12.3 Leaking Gauge Glass on Surface Condenser Boot 157
12.4 Condensate Pump Cavitation Due to Air Leaks 161
12.5 Condensate Back-Up in Surface Condenser Boot 162
12.6 Experiment with Condensate Back-Up 165
12.7 Condensate Back-Up 166

13 Seal Leg Drainage 169
13.1 Sludge Accumulation in Seal Drum 169
13.2 Seal Leg Leak Inside Seal Drum 171
13.3 Seal Leg Flange Leak Outside Seal Drum 174
13.4 Seal Leg Design 177
13.5 Inadequate Seal Leg Length for Hydrocarbons 180
13.6 Inadequate Seal Leg Capacity 182
13.7 High Back-Pressure from Seal Drum 183
13.8 Detecting Condensate Back-Up in Seal Legs 184
13.9 Condensate Back-Up Due to Air Leak in Barometric Drain Line 186
13.10 Seal Drum Design 188

13.11 Seal Drum Fills with Corrosive Deposits 189
13.12 Seal Drum Design Tips 193
13.13 An Unfortunate Incident 194

14 Other Types of Vacuum Equipment 197
14.1 Hogging Jets 197
14.2 Use of Hogging Jet on Surface Condenser 198
14.3 Liquid Seal Ring Compressors 200
14.4 Gas Ejectors 202
14.5 Liquid Ejectors 203
14.6 Ejector Compression Efficiency 204

15 Air Baffle and Impingement Plate in Surface Condensers 205
15.1 Mechanical Configuration of Seal Strips 206
15.2 Corroded Brass Seal Strips 208
15.3 Air or Vapor Baffle Leak 208
15.4 Identifying Defective Seal Strips 209
15.5 Air Baffle Clearance 211
15.6 Fouling Mechanism in Vacuum Tower Surface Condensers 212
15.7 Surface Condenser Impingement Plate 212
15.8 Oversized Impingement Plate 214
15.9 Impingement Plates as Vapor Distributors 215

16 Optimizing Vacuum Tower Operation 217
16.1 Steam to Heater Passes 218
16.2 LVGO Pan Level Loss Causes a Loss in Vacuum 220
16.3 Carry-Over of LVGO Pumparound Spray 226
16.4 Optimizing Vacuum Tower Top Temperature 227
16.5 Plugged Vacuum Tower Top Demister 229
16.6 Bypassing Primary Ejector 232

17 Frequently Asked Questions 233
17.1 Vacuum Systems 233

The Norm Lieberman DVD/Video Library 243
Index 247